# Exhibit D

## (REDACTED VERSION OF DOCUMENT TO BE SEALED)

# Exhibit 32
# (Submitted Under Seal)

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**EXPERT REPORT OF KIRILL LEVCHENKO**

October 28, 2019

Corrected on May 12, 2020

# Counts vs. General Motors

Case No. 1:16-cv-12541-TLL-PTM

Highly Confidential – Subject to Protective Order
*U.S. District Court – Eastern District of Michigan*

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# I. INTRODUCTION

1. I am submitting this report on behalf of the Plaintiffs in the above-captioned action. I have been retained as a technical expert to study and provide my opinions regarding the design of the software in the 2014 Chevy Cruze passenger cars with a diesel engine. Specifically, I was asked to review two potential cycle-beating strategies implemented in software [redacted] My opinions, as well as the evidence I rely upon to support them, are set forth in detail in this report. The contents of all appendices and exhibits identified herein are incorporated, in their entirety, by such reference.

2. My analysis and opinions pertain to the EDC17 Engine Control Unit (ECU) used in 2014 Chevy Cruze passenger cars with a diesel engine. The ECU is a computer that controls nearly all aspects of a vehicle's engine and exhaust treatment, including mechanisms designed to reduce harmful tailpipe emissions. For example, the ECU controls the position of the Exhaust Gas Recirculation (EGR) valve, which determines how much exhaust gas is sent back into the cylinder air intake. EGR is one of the technologies used to reduce emissions of Nitrogen Oxides (NOx), one of the pollutants regulated by the EPA. The ECU also controls the SCR system. In particular, the ECU calculates how much DEF is sprayed into the exhaust gas stream. DEF is a mixture of water and urea that reacts with the NOx in the exhaust gas and converts it to benign Nitrogen gas and water vapor. Computerized engine control gives carmakers precise moment-to-moment control over how a vehicle behaves under different conditions. For example, the

software on the ECU of the Chevy Cruze can vary the amount of exhaust gas recirculated based on outside air temperature or change how much DEF is injected into the exhaust based on the temperature of the exhaust gas. This level of fine-grained control also makes it possible for carmakers to circumvent emissions testing by making a car behave one way during an emissions test, and another way when driven day-to-day by their customers.

3. In preparing this report, I used methods and analyses of a type reasonably relied upon by experts in my field in forming opinions or inferences on the subject. The opinions expressed are based upon a reasonable degree of certainty.

4. To analyze the software code in the 2014 Chevy Cruze diesel vehicles, I took the following steps:

a. I reviewed the software documentation provided by GM for the EDC17 ECU (GMCOUNTS000115370). I assume the software documentation to be an accurate description of the behavior of the software itself. Specifically, I assume that the function block diagrams shown in the documentation are a faithful graphical representation of the function blocks developed using ASCET software and that the executable code for the EDC17 was synthesized from these blocks.

b. I used calibration data stored in DCM files in documents provided by Bosch to arrive at the complete description of how the software is expected to behave in a vehicle. I assume that the DCM files accurately describe the calibration data that is included in the production vehicles. In furtherance of this assumption, I rely on the following information:

  - The context in which a file occurs, such as a file being included as an email attachment.

- References to the file name in other documents, such as spreadsheets and email messages.
- The date and time appearing in DCM file metadata.
- The name of the DCM file, which may include a software revision number corresponding to a specific deliverable to General Motors LLC from Bosch LLC.

5. After carefully reviewing relevant documents, I have formed the following opinions regarding the EDC17 software as programmed in the Chevy Cruze diesel vehicles:

[redacted]

[redacted]

6. Between now and such time that I may be asked to testify before the Court, I expect to continue my review, evaluation, and analysis of information generated during discovery, as well as of relevant evidence presented before and/or at trial. I also expect to review the reports submitted by General Motors and Bosch LLC experts. I reserve the right to amend or supplement this report, as necessary (and as acceptable to the Court). I also reserve the right to develop materials and exhibits as appropriate for use in helping to demonstrate and explain my opinions if I am asked to testify at trial.

## II. BACKGROUND AND QUALIFICATIONS

7. I am an Associate Professor in the Department of Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign. I obtained my Ph.D. in Computer Science and Engineering from the University of California, San Diego, in 2008. My doctoral studies focused on networking, computer security and related technologies. Before my current appointment at the University of Illinois in the Fall of 2019, I was a Research Scientist at the University of California, San Diego.

8. I specialize in computer networks and computer security. I have authored over 40 peer-reviewed articles on the subject of computer networks and computer security, including the security of cyber-physical systems. Some of my computer security research entails reverse-engineering software and hardware systems, which is directly relevant to this case. I have also received grant support from the U.S. National Science Foundation to develop technical foundations for complex secure cyber-physical systems (NSF award number 1646493). My qualifications for forming the opinions set forth in this report are listed in this section as well as in Appendix A, which is my curriculum vitae and includes a list of my publications.

9. In May 2017, my co-authors and I presented an article titled “How They Did It: An Analysis of Emission Defeat Devices in Modern Automobiles” at the 2017 IEEE Symposium on Security & Privacy. The IEEE Symposium on Security & Privacy is a top-tier, highly-selective computer security conference; articles presented at the IEEE Symposium on Security & Privacy are peer-reviewed and appear in the published proceedings of the conference. The “How They Did It” article described the technical operation of the defeat device in Volkswagen automobiles. The analysis in the article relied on the EDC17 ECU software documentation produced by Robert Bosch GmbH for Volkswagen vehicles. The article also described another defeat device used in the European-market diesel Fiat 500X, which also used the Bosch EDC17 ECU.

10. I bill Plaintiffs for my time at the hourly rate of $500 per hour for my work in this litigation, plus reimbursement for travel and other out-of-pocket expenses incurred during my work on this matter. I am compensated regardless of the facts I know or discover and/or the conclusions or opinions I reach. I have no personal or financial stake or interest in the outcome of this matter.

## III. EVIDENCE AND ANALYSIS

### A. Framework for evaluating the ECU and calibration data.

11. The ECU is a specialized computer that is responsible for controlling nearly all aspects of engine operation as well as the operation of the emissions control system. In a diesel engine, this includes controlling:

**a.** The timing and amount of fuel injected into the cylinder, which determines the amount of energy released in combustion and the characteristics of the combustion process;

**b.** The position of the throttle valve, which determines the amount of fresh air used in combustion;

c. The position of the EGR valve, which determines the amount of exhaust gas diverted back into the cylinder air intake; and

d. The amount of DEF injected into the exhaust before entering the SCR catalyst, which determines how much of the NOx is converted into nitrogen gas and water vapor before leaving the tailpipe.

12. Because EGR and SCR are two of the primary mechanisms used to control the emission of NOx, the ECU plays a critical role in controlling vehicle emissions.

13. EGR offers a complex set of tradeoffs, reducing NOx emissions on the one hand, and increasing particulate emissions on the other. The figure below illustrates some of these tradeoffs[1]:

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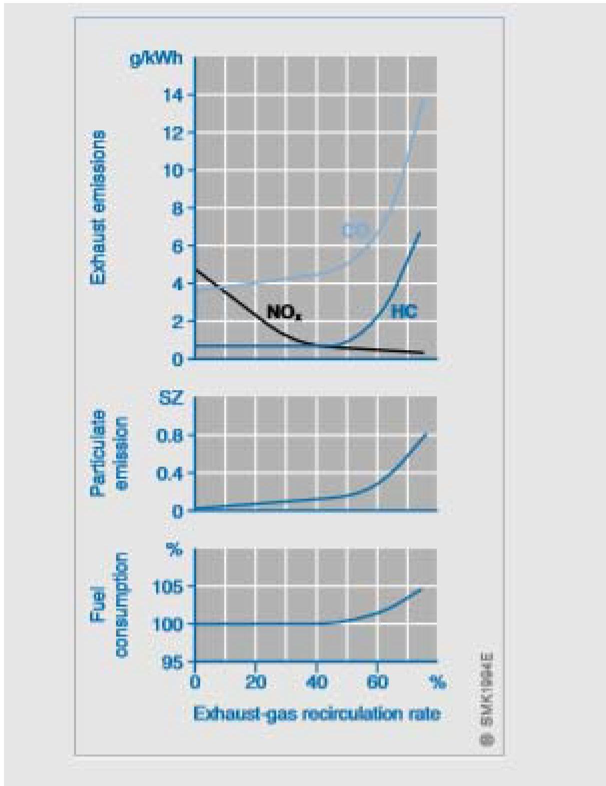
[1] Konrad Reif, ed. *Diesel Engine Management: Systems and Components*. Bosch Professional Automotive Information, (Springer Vieweg, 2014), 198.




Similarly, the amount of DEF used must also be carefully controlled. Excess DEF dosing results in the emission of ammonia, another pollutant, as well as requiring more frequent refills.

14. The ECU performs these functions by collecting data from sensors throughout the vehicle, calculating an appropriate response, and sending signals to actuators, as illustrated in the following figure[2]:

[2] Ibid, 220.

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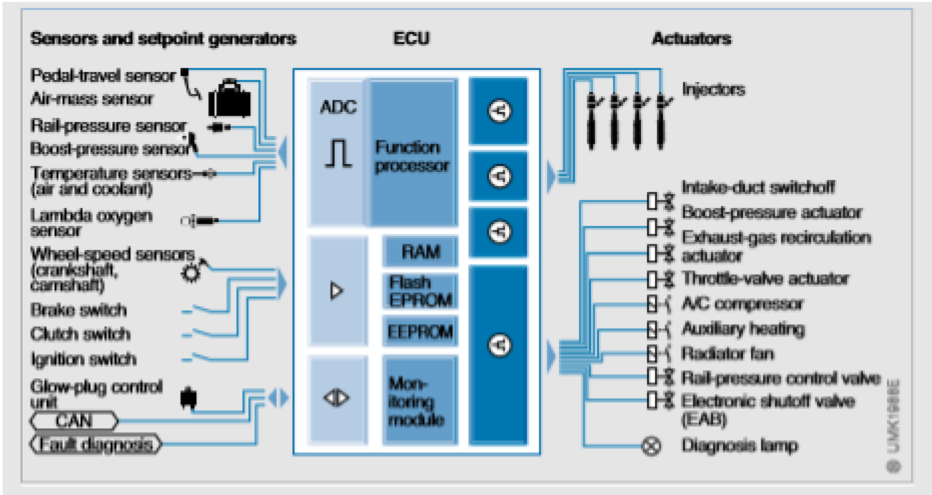


This operation—read sensor data, calculate, generate control signals—happens many times per second. The calculations necessary to generate the appropriate control signals in response to measured inputs are performed by the ECU.

15. ECU software is structured as a fixed set of calculations that are performed in each calculation cycle. These calculations are described using a visual block diagram language, an example of which is shown in the following figure, taken from page 5282 of the software documentation (GMCOUNTS000115370):

[redacted]

By convention, inputs appear on the left and output on the right, with the calculation generally proceeding left-to-right, with signals moving along lines in the figure similar to how electrical signals would move along a wire. [redacted]

16. These diagrams are produced using a program called ASCET, which can then also translate the diagram into machine language that can be executed by the CPU inside the ECU. These diagrams, therefore, serve both as a human-readable description of the calculations taking place inside an ECU and as the computer-readable formal description of the calculations, which ASCET turns into the executable code.

17. In addition to the signals, some of which represent external measurements and some the intermediate results of calculations, the design language includes constant values [redacted] These values are programmed into the ECU alongside the program and remain fixed during its operation. The choice of values for these constants can alter the behavior of the ECU. In the upper left of the figure, for example, the signal [redacted]

[redacted]

18. In the ECU development process, creating the block diagrams, which define the calculations, is a logically separate process from choosing values for the constants appearing in the calculation. The latter is called c*alibration*, and may be carried out by a separate team. Calibration allows an ECU to be fine-tuned for a specific vehicle.

19. To answer the questions posed to me by Plaintiffs' counsel (paragraph 1), I examined the diagrams and accompanying text provided by GM in the software documentation. Although I have not used ASCET software, which was used to create the diagrams and which is used to generate executable code from the diagrams, I was comfortable analyzing this documentation for the following reasons:

a. First, block diagram languages, as a means of formally specifying the behavior of a system, are well known in computer science and engineering. The "Introduction to Computing" course I am teaching this semester, for example, uses block diagrams to describe the operation of digital circuits. Higher-level block

diagrams, including lines to represent signal flow, are used throughout my discipline to illustrate complex systems.

b. Second, the specific symbols and blocks used by ASCET are either standard or defined in ASCET documentation. For example, the [&] block used in the diagram above is a standard symbol (IEEE Standard 91-1984). The ASCET documentation defines the meaning of more complex non-standardized symbols. Some symbols are defined in the software documentation itself.

c. Third, in addition to the block diagrams, I considered the text accompanying the diagrams to ensure that it agreed with the diagram. In all but one case, noted in Appendix C, the textual description agreed with the diagram.

[redacted]

[redacted]

[redacted]

[redacted]

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[redacted]

[redacted]

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[3] Ibid, 204.

[redacted]

## IV. DOCUMENTS CITED AND CONSIDERED

33. I have considered the production documents specifically cited herein by Exhibit and/or Bates number. In addition, I have reviewed the software documentation and calibration files produced to date. There are a tremendous number of documents in this litigation. I have had full access to the electronic database that contains documents produced by Bosch and General Motors in this litigation, and I have performed searches within that database. The materials that I relied on from the database are detailed in Appendices B and C. I am not aware of the existence of any document I have not been allowed to see.

34. I also referred to or had at hand each of the following public documents and listed below while drafting this report:

a. ASCET version 5.2 manual (for symbols used in block diagrams)

b. ETAS DCM file format specification

c. Konrad Reif, ed. *Diesel Engine Management: Systems and Components*. Bosch Professional Automotive Information. Springer Vieweg, 2014.

d. Section "[CdGen 1.6.1_DS;1] ASCET Automotive System Library Interface" from EDC17C69 documentation used in the "How They Did It" paper.

DATED: May 12, 2020

Kirill Levchenko